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Growth Dynamics and Physiological Behaviour of Summer Groundnut (*Arachis hypogaea L.*) Genotypes Under Semi-Arid Conditions of Bundelkhand, Uttar Pradesh

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Abstract

20 bunch-type groundnut (*Arachis hypogaea L.*) genotypes were evaluated during the summer seasons of 2006 and 2007 at Rath, Hamirpur, Uttar Pradesh (25.5° N, 79.7° E) to study growth dynamics, physiological behaviour and traits contributing to groundnut yield. Experiments were laid out in a Randomized Block Design (RBD) with three replications. Growth indices Leaf Area Index (LAI), Net Assimilation Rate (NAR) and Relative Growth Rate (RGR) were computed from destructive harvests at 30, 60 and 90 days after sowing (DAS). Pooled ANOVA, path coefficient analysis and stepwise multiple regression were employed to identify key physiological drivers of groundnut yield. Significant genotypic variation was recorded for plant height, branching, dry matter accumulation and its partitioning among plant parts. Genotypes ICGV 93468 and ICGV 00298 exhibited superior LAI and NAR during the critical 30–60 DAS interval, indicating efficient source establishment and effective dry matter allocation to pods. Path analysis identified LAI at 60 DAS as the principal direct driver of groundnut yield. These genotypes are recommended for summer groundnut cultivation in the Bundelkhand region.

Keywords: *Arachis hypogaea*, Leaf Area Index, Net Assimilation Rate, Relative Growth Rate, dry matter partitioning, path coefficient analysis, summer groundnut, Bundelkhand

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Introduction

India is a major producer of oilseeds and a significant importer of vegetable oils. Rising population and increasing per capita consumption of edible oils have widened the gap between domestic production and consumption, underscoring the need to enhance oilseed productivity through improved technologies and high-yielding genotypes (Sharma *et al.*, 2022). Among oilseed crops, groundnut ranks first in India in area and contribution to total oilseed production (Directorate of Economics & Statistics, 2023). National groundnut yield, however, remains considerably below the potential demonstrated in front-line demonstrations, indicating scope for substantial improvement through better varietal selection and crop management (ICAR-AICRP Groundnut, 2021).

The cultivated groundnut (*Arachis hypogaea L.*) encompasses several botanical groups. Spanish and Valencia types are bunch-habit, early-maturing genotypes suited to intensive cropping systems, whereas Virginia types are spreading and late-maturing, showing markedly different growth behaviour. These differences highlight the importance of characterising physiological and growth traits across genotypes (Bera *et al.*, 2019). Declining groundnut cultivation in certain regions due to biotic stresses and unsuitability of long-duration varieties has reinforced demand for short-duration, high-yielding and disease-resistant genotypes (Kumar *et al.*, 2020). Summer cultivation under controlled irrigation offers comparatively stable thermal conditions and has shown higher groundnut yield potential than kharif or rabi seasons (ICRISAT, 2022). The Bundelkhand zone of Uttar Pradesh, though a non-traditional groundnut area, presents growing scope for summer cultivation due to irrigation availability (ICAR, 2021).

Groundnut yield is ultimately the product of photosynthetic source capacity and efficient partitioning of assimilates to developing pods. Understanding growth indices such as LAI, NAR and RGR, and their relationships with groundnut yield, is central to genotype evaluation and ideotype development (AICRP-Groundnut, 2021). The present study evaluated growth dynamics and physiological behaviour of 20 summer groundnut genotypes and identified traits driving higher productivity under semi-arid conditions of Bundelkhand, Uttar Pradesh.

Materials and Methods

Experimental Site and Environment- Field trials were conducted during the summer seasons of 2006 and 2007 at the research farm, Rath, Hamirpur, Uttar Pradesh (25.5° N, 79.7° E). The climate is semi-arid subtropical with maximum summer temperatures reaching 45°C. Soil was silty loam with pH 7.60, 0.51% organic carbon and 0.06% total nitrogen.

Experimental Design and Crop Management- 20 bunch-type groundnut genotypes were evaluated in a Randomized Block Design (RBD) with three replications. Sowing was on 10 March 2006 and 11 March 2007 at 30 × 10 cm spacing. A basal dose of N: P_2O_5:K_2O: Gypsum: Borax at 25:40:50:200:5 kg ha^{-1} was applied at sowing.

Growth and Physiological Measurements-Three plants per plot were sampled destructively at 30, 60 and 90 DAS. Leaf area was measured using a LI-3100 area meter (cm^2 plant^{-1}). The following growth indices were computed:

- Leaf Area Index (LAI): Total leaf area per plant / Land area occupied per plant
- Net Assimilation Rate (NAR, g m^{-2} day^{-1}): $[(W_2 - W_1)(\ln L_2 - \ln L_1)] / [(L_2 - L_1)(t_2 - t_1)]$
- Relative Growth Rate (RGR, mg g^{-1} day^{-1}): $(\ln W_2 - \ln W_1) / (t_2 - t_1)$

Where W_1 and W_2 are dry weights, and L_1 and L_2 are leaf areas at times t_1 and t_2, respectively.

Statistical Analysis-Data from both years were subjected to pooled analysis of variance (ANOVA) after confirming homogeneity of variance ($F^{obs} = 1.85 < F_{0.05} = 4.03$). Path coefficient analysis partitioned genotypic correlations into direct and indirect effects on groundnut yield. Stepwise multiple regression was employed to develop a predictive yield model from physiological parameters.

Results and Discussion

Plant Height and Branching-Significant variation in plant height was observed among genotypes (Table 1). ICGV 99195 (30.22 cm), ICGV 00298 (29.22 cm) and ICGS 11 (28.28 cm) were the tallest, while Dh 86 (19.95 cm), ICGV 02022 (20.89 cm) and ICGV 93468 (21.22 cm) were among the shortest. Such variation is largely governed by genetic constitution and has been reported by Kumar *et al.* (2019), Sharma *et al.* (2020) and Reddy *et al.* (2021).

Branching was superior in ICGV 02022, G 201, ICGV 86325, ICGV 99195, ICGS 76, ICGV 94361, ICGS 44 and ICGV 00298 (Table 1). Greater branching provides more axillary nodes for peg and pod initiation, contributing indirectly to groundnut yield (Singh *et al.*, 2019; Patel *et al.*, 2021; Meena *et al.*, 2022).

Table 1: Plant height (cm) and number of branches per plant of groundnut genotypes (pooled mean of 2006 and 2007)

S.No.	Genotype	Plant Height (cm)	No. of Branches per Plant
1.	Dh 86	19.95	4.39
2.	Dh 40	24.28	4.50
3.	R 9251	24.89	5.28
4.	R 8808	21.28	5.61
5.	R 2000-1	23.28	5.17

6.	ICGS 44	21.94	6.28
7.	ICGS 1	23.61	4.50
8.	ICGS 37	22.55	5.28
9.	ICGS 11	28.28	5.61
10.	ICGS 76	20.89	6.39
11.	ICGV 93468	21.22	5.28
12.	ICGV 86590	26.61	6.17
13.	ICGV 86325	25.94	6.50
14.	ICGV 00310	23.61	5.28
15.	ICGV 00298	29.22	6.28
16.	ICGV 99195	30.22	6.50
17.	ICGV 02099	20.94	4.50
18.	ICGV 02022	20.89	6.61
19.	ICGV 94361	24.50	6.39
20.	G 201	25.55	6.61
	Mean	23.98	5.66
	S.Ed. ±	0.72	0.21
	C.D. (P=0.05)	**1.43**	**0.41**

Dry Matter Partitioning among Plant Parts-The proportion of total plant dry matter allocated to pods varied widely across genotypes (Fig. 1). ICGV 93468, Dh 86 and ICGV 00298 showed the highest pod dry matter percentage (60.0% each), while G 201 and Dh 40 allocated proportionately more dry matter to vegetative parts (45.0% to pods). Efficient source–sink translocation favouring reproductive sinks is associated with higher groundnut yield (Rani *et al.*, 2020; Yadav *et al.*, 2022). The high pod dry matter percentage of ICGV 93468 and ICGV 00298 confirms their superior assimilate partitioning efficiency.

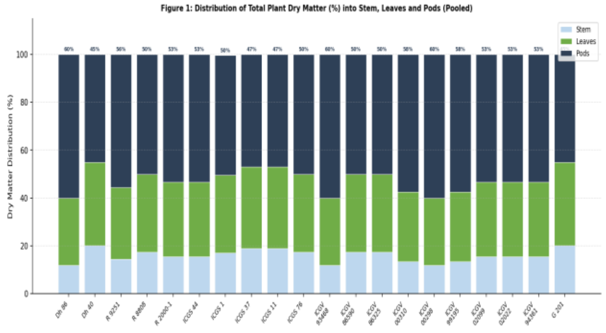

Fig. 1: Distribution of total plant dry matter (%) into stem, leaves and pods of groundnut genotypes (pooled mean).

Dry Matter Accumulation in Plant Parts-Pod dry matter per plant was highest in ICGV 00298 (19.65 g), R 9251 (20.33 g) and ICGS 44 (20.36 g plant⁻¹), while total plant dry matter was greatest in ICGS 37 and ICGS 11 (38.99 g plant⁻¹ each), largely due to higher vegetative investment (Fig. 2). Genotypes ICGV 93468 and ICGV 00298 combined moderate total biomass with a high pod fraction, reflecting a favourable harvest index. Differences in dry matter accumulation are attributable to variation in leaf area, photosynthetic efficiency, nitrogen metabolism and assimilate partitioning (Rao *et al.*, 2019; Kumar *et al.*, 2021; Singh *et al.*, 2023).

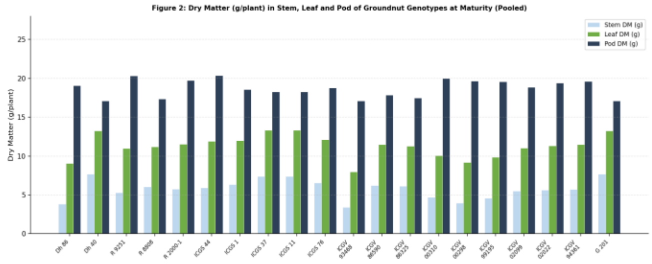

Fig. 2: Dry matter (g plant⁻¹) in stem, leaf and pod of groundnut genotypes at maturity (pooled mean).

Net Assimilation Rate-NAR was consistently higher during 60–90 DAS than 30–60 DAS across all genotypes (Table 2), reflecting increased photosynthetic demand during pod filling. During 30–60 DAS, Dh 86 (2.763), ICGV 02099 (2.467) and ICGV 93468 (2.424 g m⁻² day⁻¹) recorded the highest NAR. At 60–90 DAS, Dh 86 (4.532) led, followed by ICGV 00298 (3.654) and ICGV 02099 (3.634 g m⁻² day⁻¹). Higher NAR in ICGV 93468 and ICGV 00298 during the vegetative phase reflects greater photosynthetic efficiency per unit leaf area, which translates into superior dry matter allocation to pods. NAR values are presented in tabular form given their importance in path coefficient analysis of groundnut yield.

Table 2: Net Assimilation Rate (NAR; g m⁻² day⁻¹) of groundnut genotypes at 30–60 and 60–90 DAS (pooled mean of 2006 and 2007)

S.No.	Genotype	NAR at 30–60 DAS (g m⁻² day⁻¹)	NAR at 60–90 DAS (g m⁻² day⁻¹)
1.	Dh 86	2.763	4.532
2.	Dh 40	2.567	4.135
3.	R 9251	2.081	3.469
4.	R 8808	2.035	3.432
5.	R 2000-1	2.245	3.305
6.	ICGS 44	2.013	3.150
7.	ICGS 1	2.117	3.188
8.	ICGS 37	2.032	3.132
9.	ICGS 11	1.991	3.116
10.	ICGS 76	2.080	3.126
11.	ICGV 93468	2.424	3.477
12.	ICGV 86590	2.256	3.480
13.	ICGV 86325	2.159	3.206
14.	ICGV 00310	1.830	2.924
15.	ICGV 00298	2.415	3.654
16.	ICGV 99195	2.392	3.328
17.	ICGV 02099	2.467	3.634
18.	ICGV 02022	2.190	3.336
19.	ICGV 94361	2.220	3.306
20.	G 201	2.153	3.510
	Mean	2.221	3.422
	S.Ed. ±	0.067	0.105
	C.D. (P=0.05)	**0.132**	**0.210**

Leaf Area Index-LAI increased progressively from 30 to 60 DAS before declining at 90 DAS as leaf senescence set in (Fig. 3). At 60 DAS, ICGV 93468 (3.94), ICGV 00298 (3.88) and ICGV 99195 (3.86) recorded the highest LAI, indicating rapid canopy expansion coinciding with pod initiation. Path coefficient analysis confirmed LAI at 60 DAS as the single most important direct driver of groundnut yield (direct effect = 0.621), providing the photosynthetic surface required to sustain pod development under high-temperature stress. Genotypes with low LAI at 60 DAS, such as G 201 (3.18) and Dh 40 (3.22), correspondingly showed lower groundnut yield. Similar findings have been reported by Gupta *et al.* (2022).

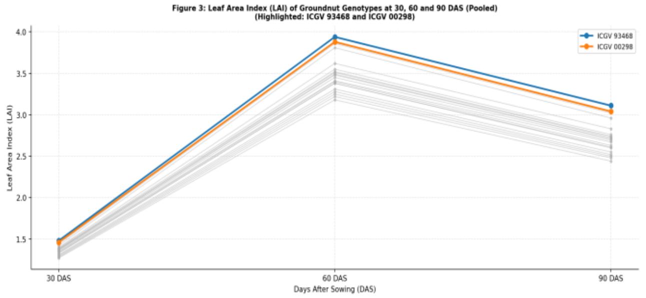

Fig. 3: Leaf Area Index (LAI) of groundnut genotypes at 30, 60 and 90 DAS (pooled mean). ICGV 93468 and ICGV 00298 highlighted; remaining genotypes shown in grey.

Relative Growth Rate-RGR was markedly higher during 30–60 DAS than 60–90 DAS across all genotypes (Fig. 4), consistent with the transition from vegetative expansion to reproductive growth. During 30–60 DAS, ICGV 99195 (25.7), R 2000-1 (25.2) and ICGS 1 (25.2 mg g⁻¹ day⁻¹) showed the highest RGR, reflecting vigorous early canopy building. At 60–90 DAS, values converged across genotypes as reproductive growth dominated, with R 8808 (14.9) and Dh 40 (14.8 mg g⁻¹ day⁻¹) marginally highest. High early-season RGR is critical for rapid canopy closure before peak summer temperatures, thereby extending the effective photosynthetic period and supporting higher groundnut yield. Stepwise regression confirmed early RGR (30–60 DAS) as a significant predictor of groundnut yield, underscoring its value as a selection criterion.

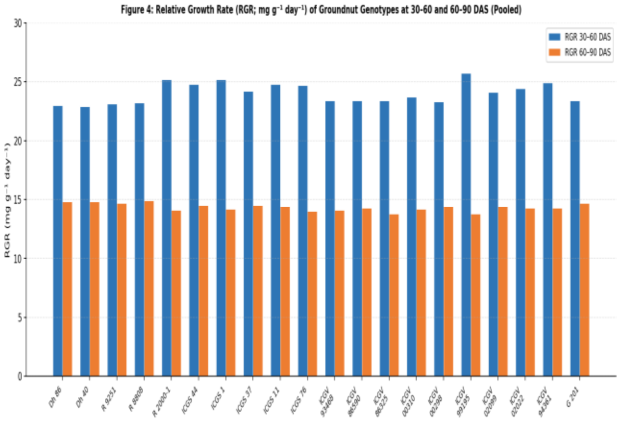

Fig. 4: Relative Growth Rate (RGR; mg g^{-1} day^{-1}) of groundnut genotypes at 30–60 and 60–90 DAS (pooled mean).

CONCLUSION

Among 20 summer groundnut genotypes evaluated, ICGV 93468 and ICGV 00298 emerged as physiologically superior, combining rapid early-season canopy expansion (high RGR and LAI at 30–60 DAS), sustained photosynthetic efficiency (NAR) through pod filling, and efficient dry matter partitioning towards reproductive sinks. Path analysis identified LAI at 60 DAS as the primary driver of groundnut yield, supported by positive contributions of NAR and early RGR. These genotypes are recommended for wider adoption in summer groundnut cultivation in the Bundelkhand region of Uttar Pradesh and as parents in physiological breeding programmes targeting semi-arid environments.

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